Empirical Mode Decomposition analysis of Sleep EEG

Empirical Mode Decomposition analysis of Sleep EEG:
Examining the microstructure of transient oscillatory events.

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Most methods of EEG analysis (e.g. Fourier Transform) rely on assumptions of linearity and stationarity; EEG signals however are known to have non-linear and non-stationary properties, showing oscillatory activity with frequency, amplitude and phase varying continuously and unpredictably.

Studies using nonlinear methods to study EEG state transitions as seen in anaesthesia and sleep (Xiaoli et al., 2008) have suggested they can provide additional information not accessible with linear methods and may also be more sensitive at discriminating between sleep stages (Fell et al., 1996).

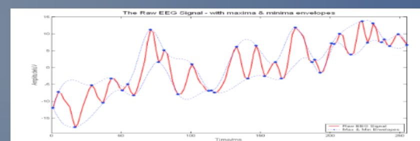
Method:

Empirical Mode Decomposition (EMD) is a data-driven method for decomposing a complex oscillatory signal into its constituent frequency components.

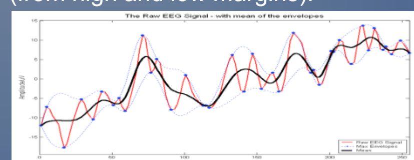
EMD does not rely on assumptions of stationarity and can reveal information about instantaneous (time-varying) changes in the frequency, phase and amplitude of the signal. EMD is well suited for studying inherently unpredictable complex dynamical systems (e.g. the weather & the brain) and is increasingly being applied in EEG research (e.g. Burgess, 2012).

We describe an application of EMD in the study of characteristic sleep EEG phenomena (spindles and K-complexes), which due to their transient, unpredictable occurrence and variable morphology are notoriously difficult to study using traditional methods. EMD is described as follows:

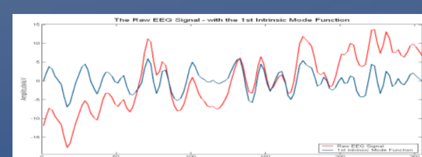
The maxima and minima (peaks & troughs) of the raw EEG are identified, and the envelope of the signal is plotted:



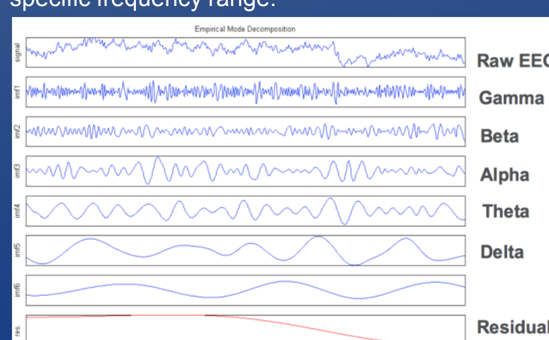
The mean of the envelope is then calculated (from high and low margins):



This mean is subtracted from the original raw EEG signal; this produces the first Intrinsic Mode Function (IMF):

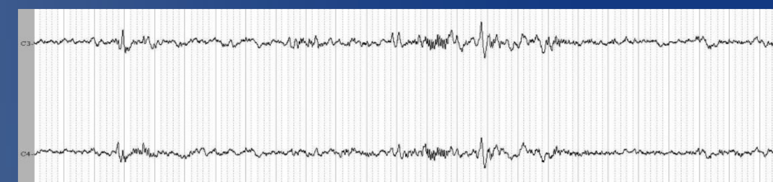


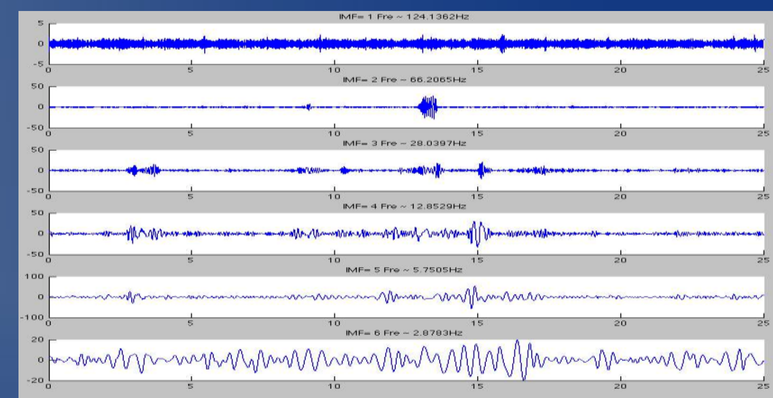
This process is repeated iteratively generating further IMFs of decreasing frequency, each containing oscillatory components of the original signal of specific frequency range:



Data:

Sleep EEG was recorded from one healthy volunteer from C3 & C4 (sampling: 500Hz; bandpass: >.02Hz <80Hz). Artefact-free epochs (25s) were selected from Stage 2 sleep containing prominent sleep spindles and K-complexes.





Results:

EMD decomposed the raw EEG epoch above into six Intrinsic Mode Functions, each showing evoked activity within specific frequency ranges, which are empirically derived (i.e. not pre-specified).
The first (top) IMF consists of high-frequency EMG activity, demonstrating that EMD can also remove noise without filtering (which can introduce phase distortions). The lower IMFs (especially IMFs 3-5), show changes in oscillatory activity related to the K-complexes and spindles seen in the raw EEG.
These images suggest that by separating such sleep oscillatory events into frequency bands, while also showing their evolution in time, EMD can provide unique insights into their makeup. Further exploration of sleep EEG events with this method can be helpful in understanding their nature and function.

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